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CLINICAL COMMENTARY

# A PHASED REHABILITATION PROTOCOL FOR ATHLETES WITH LUMBAR INTERVERTEBRAL DISC HERNIATION

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## ABSTRACT

Conservative non-surgical management of a herniated lumbar intervertebral disc (HLD) in athletes is a complex task due to the dramatic forces imparted on the spine during sport participation. The demands placed upon the athlete during rehabilitation and return to sport are unique not only from a sport specific perspective, but also regarding return to the sport strength and conditioning programs utilized for sport preparation. Many prescriptions fail to address postural and motor control faults specific to athletic development, which may prevent full return to sport after suffering a HLD or predispose the athlete to future exacerbations of a HLD. Strength exercises involving squatting, deadlifting, and Olympic power lifts are large components of the typical athlete's conditioning program, therefore some progressions are provided to address potential underlying problems in the athlete's technique that may have contributed to their HLD in the first place. The purpose of this clinical commentary is to propose a framework for rehabilitation that is built around the phases of healing of the disc. Phase I: Non-Rotational/Non-Flexion Phase (Acute Inflammatory Phase), Phase II: Counter rotation/Flexion Phase (Repair Phase), Phase III: Rotational Phase/Power development (Remodeling Phase), and Phase IV: Full return to sport. This clinical commentary provides a theoretical basis for these phases based on available literature as well as reviewing many popular current practice trends in the management of an HLD. The authors recognize the limits of any general exercise rehabilitation recommendation with regard to return to sport, as well as any general strength and conditioning program. It is vital that an individual assessment and prescription is made for every athlete which reviews and addresses movement in all planes of motion under all necessary extrinsic and intrinsic demands to that athlete.

***Key Words:*** Athletes, herniated lumbar disc, rehabilitation

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## INTRODUCTION

Conservative non-surgical management of a herniated lumbar intervertebral disc (HLD) in an athlete is a complex task due to the dramatic forces imparted on the spine during sport participation.[1] The role of exercise prescription and manual interventions in the treatment of an HLD has evolved based on increased understanding of the injury and biomechanical healing properties of the intervertebral disc. To the best knowledge of the authors, no suggestion for phased HLD rehabilitation protocol for use with athletes has previously been published. The demands placed upon the athlete during rehabilitation and return to sport are unique not only from a sport specific perspective, but also regarding return to the sport strength and conditioning programs utilized for sport preparation. Traditionally, exercise prescription from a rehabilitation point of view may miss the opportunity to address readiness for both return to the strength and conditioning program, and the sport itself. Many prescriptions fail to address postural and motor control faults specific to athletic development, which in turn may prevent full return to sport after suffering a HLD or predispose the athlete for future exacerbations of a HLD.

The purpose of this clinical commentary is to propose a framework for rehabilitation that is built around the phases of healing of the disc. Within this framework the authors will propose and review some common, as well as relatively uncommon exercises, which fit within each of the phases of healing. These exercises selections are based on their ability to be integrated and progressed into the high level demands of many athletes' sports as well as their strength and conditioning programs. Strength exercises involving heavy squatting, deadlifting, and Olympic power lifts are large components of the typical athlete's conditioning program, therefore the authors will provide some suggested progressions to address potential underlying problems in the athlete's technique that may have contributed to their HLD in the first place. By no means is the intent of this framework intended to be a "cookbook". No textbook or commentary will ever substitute for clinical reasoning. With this taken into consideration, we ultimately leave exercise selection, progression, and regression in the hands of the individual clinician, based on clinical experience and athlete response. The authors want to recognize the limits of any general exercise rehabilitation recommendation with regard to return to sport, as well as any strength and conditioning program. The exercises suggested in this protocol are, at best, suited for the return to strength and conditioning phase that occurs prior to return to sport. It is vital that an individual assessment and prescription is made for every athlete which reviews and addresses movement in all planes of motion under all necessary extrinsic and intrinsic demands to that athlete. This careful assessment may identify and help address potential problems in movements, which may have contributed, to their injury. Although not well described in the published literature, the authors have found clinical value in the assessment processes developed by the Gray Institute for Functional Applied Science.[2]

This clinical commentary is divided into two parts. The first presents an overview of and rationale for the phasing of the protocol. The second part is an extended appendix describing individual exercises that could be utilized within each phase and the evidence that was used in determining their selection.

## ANATOMY

Examination procedures and therapeutic interventions for pathologies of the lumbar spine are incredibly diverse; however, scientific foundations in anatomy and biomechanics should guide these procedures. Fundamental to the understanding of intervention for a multitude of low back pathologies is the understanding of the anatomy of the intervertebral disc and vertebral endplates of the lumbar vertebral bodies.

Although a thorough discussion of anatomy and biomechanics of the lumbar spine is beyond the intent of this clinical commentary, a short refresher is important. Lumbar spine anatomy has been described comprehensively by a number of authors.[3-5] Thorough descriptions and depictions of anatomical relationships that exist in the lumbar spine can be accessed in textbooks such as Gray's Anatomy,[6] and the authors defer those detailed anatomical descriptions to other sources. Instead, the intent of the current review is to describe relevant anatomy from a clinical perspective. It is important that the reader be able to apply fundamental anatomic and biomechanical information to the selection of any intervention for the lumbar spine. A brief overview of the intervertebral disc and body articulations will be presented in order to provide a basis for the premise of healing of the HLD.

## DISCS AND INTERVERTEBRAL BODY ARTICULATIONS

The interposing discs provide a measure of shock absorbing protection to the spinal column and appropriate stability for the spine during load bearing activities.[3,5] Essentially, the discs are composed of three components, none of which are clearly delineated from the other. The components are the nucleus pulposus (NP), the annulus fibrosus, and the vertebral endplates.

The nuclear portion of the disc is comprised largely of water but contains a few cartilage cells and collagen fibers. It has the consistency of toothpaste[3] or phlegm.[5] It has water-binding properties afforded to it by the presence of a large measure of ground substance, composed primarily of proteoglycans.[7] These proteoglycans attract water, which supports the disc's structural integrity through the covalent binding properties between the ground substance and the collagen fibers.[8,9] The primary function of the disc is to sustain and transmit pressure that is exerted through the vertebral column. This pressure or force exerted on the spine occurs during weight bearing and torsional movements, and the compressive forces absorbed by the NP assist in protection of the annulus.[10]

Transition from the NP to the annulus fibrosis of the disc is gradual and occurs from the central portion of the disc when moving laterally in any direction. There are no clear boundaries of demarcation between the NP and the annulus.[7,10] The annular fibers become progressively more distinct toward the periphery of the disc. Its fibers are arranged in alternately oriented concentric ring layers which contribute to the tensile strength of the annular ring.[7] The annular fibers are thicker anteriorly than posteriorly, which probably contributes to the tendency of nuclear matter to extrude posteriorly in most clinical cases.[3]

Articulated spinal vertebrae and the intervening disc form a unit known as the spinal segment. A spinal segment is comprised of intervertebral body joints (superior and inferior) anteriorly, and the zygapophysial joints posteriorly.[11] The disc intervenes anteriorly and is intimate with the vertebral endplate of the segments above and below. These endplates are not distinctly part of the disc. In fact, they are best viewed as parts of the vertebral bodies.[12] The endplates cover the entire NP of the disc but do not completely cover the annulus (contacts only the inner annulus), and are strongly attached to the disc while only weakly attached to the vertebral body.[12]

## SPINAL INSTABILITY AND HLD

Although debate continues regarding a standardized definition and classification of spinal stability,[13] the Panjabi model of spinal stability remains central to many current definitions.[14,15] Mechanical stability of the spine is necessary in order to permit and control movement, carry loads, and protect the spine and the nerve roots. The spinal stability system must adapt to both static and dynamic loads. Panjabi defines segmental spine stability through three subsystems (Figure 1); the passive (ligamentous) subsystem, the active (musculotendinous) subsystem, and the neural control subsystem. It is important to note that all subsystems play an integrated role, none functions independently from the others. The passive subsystem consists of the vertebrae, intervertebral discs, ligaments, joint capsules, and zygapophyseal joints. The passive subsystem physically resists forces only towards the end range of motion, by which it obtains its passive definition; however its primary function goes far beyond mere physical resistance of forces by also transmitting position and motion information to the neural control subsystem. The active subsystem provides both force generation contributing to mechanical stability

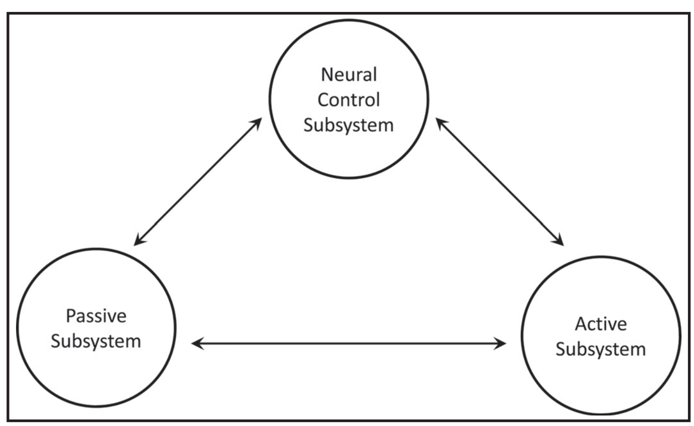


**Figure 1.** *The Panjabi Spinal Stabilizing System Model*

through all ROM and proprioceptive and kinesthetic feedback. The neural control system receives positional and velocity information from both the passive and active subsystems and instructs the active system on how to adapt in order to achieve stability. For additional information regarding the importance of feedback via the neural control subsystem, see the two recently published articles by Reeves et al.[16,17] Central to these subsystems and the basis of Panjabi's definition of clinical instability is the neutral zone (NZ). The neutral zone is defined as the range of intervertebral motion, determined from the neutral position (where overall internal stresses and muscular efforts to hold posture are minimal) in which little resistance is offered by the passive structures of a spinal segment. Panjabi also described this as the zone of high flexibility or laxity, which occurs before the increased passive resistance of the elastic zone, which in turn dictates the physiological limit of segmental movement.[15] Previous definitions of clinical spinal stability emphasized terminal behavior (end range of the elastic zone, or the physiological limit) of a spinal segment, which limited a clinical diagnosis of instability to rare cases of major structural instability resulting in gross increases in ROM that occur after failure of passive structures (significant bone or connective tissue involvement).[18] The concept of the NZ provides a model that offers insight into the early movement occurring during segmental spinal motion, which is closely related to the interplay of the passive and active subsystems, providing a clinical model of spinal instability. The greater the neutral zone (or the greater the laxity prior to reaching the passive resistance of the elastic zone), the greater the degree of spinal instability. Mimura et al[19] further expanded the previous concept by proposing a ratio of NZ/ROM into an index of instability, providing a range of joint laxity as a percentage of full ROM using a cadaveric model.

Evidence regarding the relationship between disc degeneration and instability is growing. Cadaveric studies by Zhao et al[20] have revealed that tissue dehydration and endplate disruption can produce marked segmental instability, or phases of disc degeneration that may result in various degrees of segmental instability with earlier phases presenting as more unstable than later.[21,22] Additionally, in vivo demonstrations of segmental instability related to degenerative disc disease have been presented.[23-25] The demonstration of the relationship between disc degeneration and instability provides a hypothesis to support the development of a rehabilitation protocol based on stabilization protocols.

## HERNIATED INTERVERTEBRAL DISC ETIOLOGY

A recent literature review by Adams et al is informative regarding discussions on the subject of healing and the intervertebral disc.[26] Here the authors will provide an abridged overview of this review in addition to considerations from other resources. When examining healing of a HLD it is important to differentiate between the role of the nucleus, annulus, and the end plate in the process of disc degeneration. Intervertebral disc changes that occur with age are particularly evident in the NP due to its low cell count and avascular nature. Even at birth, only the annulus is vascular, and by the age of five, the annular vasculature is gradually limited toward the periphery due to weight bearing and growth during bipedal/upright development.[27,28] Guehring et al[29,30] demonstrated in animal studies that a dramatic decrease in cell density occurs between the developmental periods of 6-24 months from birth due to a loss in notochordal cells in the central region of the disc. Once skeletal maturity is reached, proteoglycan content of the NP gradually decreases, resulting in progressive dehydration with age. With decreased internal fluid pressure, less support is available from the NP and a greater percentage of compressive force must be supported by the annulus, potentially resulting in decreased disc height and peripheral bulging for some individuals. Zhao et al[20] demonstrated that these changes may be associated with passive segmental instability due to an increased NZ and increased range of motion due to the relatively slackened fibers of the annulus.

All structural changes of disc degeneration are likely to be initiated by mechanical loading. It appears that in many cases vertebral end plates may be the first point of failure.[5,20,31] McGill noted that all but two of over 400 porcine spinal trauma models compressed to failure in a neutral position at his laboratory resulted in end plate fractures.[5] Brinkmann et al and Zhao et al also demonstrated that high or repetitive axial compression loads in human cadaveric spines commonly result in vertebral end plate fracture.[20,32] Vertebral endplate changes appear common in patients with non-specific LBP, vertebral endplate changes have been reported at rates of 43% for individuals with LBP and 6% for an asymptomatic population.[33] The importance of this occurrence is that vertebral end plate fracture may result in decompression of the NP,[34] which can result in annular bulging.[31,34] This bulging may potentially set the stage for a HLD. Herniation of the intervertebral disc is associated with repeated compressive loads (1,000 + repetitions) that occur in fully flexed or bent postures.[35] Work by Adams & Hutton appears to indicate that the spinal segment must be flexed to its full end ROM in order for the disc to herniate.[36] Finally, it appears that axial rotation combined with flexion encourages radial lesions of the annulus, while axial rotation alone does not.[37]

## HEALING OF A HERNIATED INTERVERTEBRAL DISC AND THE INFLUENCE OF EXERCISE

The extent to which exercise can influence the homeostasis (including both repair and maintenance) of biological tissue has been evaluated through a number of research efforts over the years.[38-42] Most of the studies on tissue response to exercise have been performed on animal models. Homeostasis of both bony and soft tissues is maintained through the appropriate balance of activity and rest.[43]An understanding of how exercise influences biological tissues can enhance a clinician's exercise prescription through staging of healing as well as his/her analysis of how/why certain favorable or unfavorable responses develop. Therefore, the following information presented on tissue biomechanics will examine what is known about how these tissues respond to the loading that occurs during therapeutic exercise.

Reversing disc degeneration and affecting healing involving the inner annulus and NP appears to be an extremely slow process, if possible at all.[44] The low cell density appears to be prime reason for poor healing of the NP,[45] with mathematical extrapolations predicting that turnover of the highly cross-linked collagen network of the matrix and collagen half-life would require more than 100 years to complete.[46] Given that the NP is an avascular structure, homeostasis is largely managed by diffusion and bulk fluid flow, according to O'Hara et al.[47] The extent of flow across the NP is influenced by a patient's physical activity level. Given that the nuclear matrix is composed largely of Type 2 collagen, which resists the forces of compression, homeostasis would appear to be maintained best by intermittent compression and relative decompression. Theoretically, these forces would be uniformly generated by rotation around the longitudinal (y) axis of the body as the annular fibers impose some measure of compression and decompression via reciprocal (by layer) tightening and loosening of annular fibers. However, this model is somewhat speculative since the avascular NP has such low metabolic turnover (i.e., protein synthesis). Like articular cartilage, it is uncertain whether or not the innermost portions of the annulus can successfully repair following an injury. Nonetheless, Guehring et al[48] recently demonstrated that distraction of the disc promotes its rehydration, stimulates extracellular matrix gene expression, and increases the number of protein-expressing cells in rabbits. These are essential elements for homeostasis of biological tissue. Excessive compression of the disc can lead to a *decrease* in proteoglycan synthesis while a modest amount of *increase* in hydrostatic pressures can have the opposite effect.[47,49] Connecting the key points from the findings of Guehring[48] and Ishihara[49] establishes a basis by which the authors suggest a program that incorporates carefully applied axial rotation to a lumbar spine whose discs have reasonable regenerative capacity, and that this program may provide the stimulus for tissue healing.

The outer annulus, but not the inner annulus, appears to demonstrate good healing potential in animal models.[45,50,51] In as little as six weeks of healing, the annulus is able to resist significant hydrostatic pressure within the NP.[52] This may be due to the outer annulus sharing similar cells and matrix composition to tendons and ligaments, although tendons and ligaments are also surrounded by collagenous sheaths.[53,54] Rotation may also provide the basis for normal homeostatic mechanisms for the annular fibers of the disc. As noted earlier, the annular fibers of the disc are oriented in alternately oblique fiber directions. As the spine is exposed to y-axis rotation in one direction, one-half of the annular fibers are made taut while the layers alternately oriented to the tautened fibers become relatively lax. Obviously, contralateral rotation produces the exact opposite response. The fibers that are tightened will produce an approximation of the adjacent vertebral bodies to which the annular fibers are attached. The result is translation along the y-axis, or compression and relative decompression. The annular fibers are precisely and uniquely oriented to offer control to rotation about the y-axis. There have been numerous studies over the years which have demonstrated the ill effects of immobilization on collagen production and glycosaminoglycans (GAG) in ligaments.[55-57] Conversely, application of appropriate levels of tension along the lines of fiber orientation has been shown to support the homeostatic mechanisms of collagen production.[58,59] Finally, Adams et al[26] suggest that controlled rotation may aid in reducing excessive scar tissue formation within the annulus during the phases of healing after an injury.

Although the frequent occurrence of vertebral end plate fracture has been noted[5] and implicated in disc degeneration,[34] minimal research is available regarding healing of this structure. In animal studies, endplate fracture stimulates trabecular bone growth and propagation of cartilaginous tissue at the site of injury, similar to the presence of a Schmorl's node.[60] The vertebral endplate and its trabeculae are metabolically active and remodeling may occur in response to altered mechanical loading of the bone due to outer annular injury.[61,62] Antonious et al demonstrated[9,63] that a healing response may be present based on an increased level of collagen turnover at the endplate in the presence of disc degeneration. In a possible attempt by the body to improve metabolite delivery, increased vascularization of the cartilaginous endplate near the peripheral disc lesion was also noted.[64] Vascular and sensory nerve proliferation has also been noted at the endplate in degenerated human discs providing another potential representation of healing.[65]

## CURRENT PRINCIPLES AND INTERVENTION STRATEGIES FOR HLD REHABILITATION

Rehabilitation interventions for the HLD are diverse and varied. In developing this phased protocol, the authors attempted to merge current clinical practices with available research in providing suggestion for future clinical practice. Although the focus of the protocol described in this commentary is a progressive exercise intervention, there are numerous clinical practices which are important to discuss in the context of providing a supportive environment in the management of an HLD. These clinical practices include: manual therapy, addressing the Janda Pelvic Crossed Syndrome, gluteal weakness, pelvic floor and diaphragm relationship, transversus abdominis/multifidi recruitment, latissimus dorsi and thoracolumbar fascia, and stretching.

### Manual Therapy

The role of manual therapy, including mobilization, manipulation, and soft tissue interventions including trigger point therapy in the management of a HLD is beyond the scope of this article. Although caution regarding rotatory lumbar manipulation is advised,[66] manipulation has demonstrated greater improvement in pain and functional outcomes over sham treatment in treatment of patients with lumbar HLD.[67] In addition, skilled manual therapists have noted that, in their experience, appropriately utilized mobilization and manipulation above and below the involved spinal segment including addressing the pelvis, or even addressing restrictions in the lower extremity, may decrease the amount of mechanical stress placed on the HLD. Boal and Gillette[68] studied this clinical practice and demonstrated that stabilization training alone was found to be less effective than when accompanied by a course of manual therapy. Beyond mobilization and manipulation, myofascial trigger point and soft tissue restrictions are common in chronic LBP patients[69] and can even mimic HLD symptoms,[70] therefore addressing them with manual therapy may be important. Manual therapy can play an integral role in pain management and potentially provide an optimal environment for the disc to heal, in particular during early and middle stages of rehabilitation. However, as the patient progresses into later stages of rehabilitation, it is probably beneficial to deemphasize the role of manual therapy and maximize patient active contributions to rehabilitation and independence with management.

### Janda Pelvic Crossed Syndrome, gluteal weakness, and the pelvic floor and diaphragm relationship

It is difficult to speak of the active and neural control subsystem of the Panjabi spinal stability model without touching on the concepts of neuromuscular control and length tension relationships as introduced by Vladimir Janda. The classic pelvic crossed syndrome is a described imbalance between tight and short hip flexors and lumbar erectors spinae and weak or inhibited gluteal and abdominal muscles.[71] Evidence for decreased hip flexor extensibility is evident in individuals with a history of LBP.[72] However, research results are varied regarding gluteus maximus, hamstring, and erector spinae activation order.[73-77] Further yet, the practice of promoting earlier gluteus maximus activation in LBP conditions as a protective mechanism is in question, as the gluteus maximus already appears to activate earlier in individuals who experience LBP than in those who are asymptomatic both during gait[78] and with movement into hip extension from flexion.[79] Although the role of the gluteus maximus and hip extension in the HLD and LBP population is unknown at this time, decreased hip abduction and external rotation strength, have been implicated as a predictors of back and lower extremity injury.[80,81] Even though research evidence is lacking regarding the full implications of the pelvic crossed syndrome, clinical experience demonstrates significant value in identifying and addressing gluteal weakness and alterations in hip flexor length in patients in the LBP and the HLD population.

Beyond the possible role of the gluteals on the spine, interest is growing regarding the association between the pelvic floor, the diaphragm, and spinal stability. Arab et al utilized ultrasound imaging as a method of examining pelvic floor dysfunction (PFD) and found the incidence of PFD greater in their LBP group than in comparison to the asymptomatic group.[82] A series of case studies have also shown an association between aberrant motor strategies in the pelvic floor and diaphragm and sacroiliac joint pain,[83] providing a theoretical explanation for spinal instability due to dysfunction that exists in the pelvis. Research regarding the addition of a pelvic floor contraction to the abdominal activation techniques is conflicting. Previous research has demonstrated that the addition of a pelvic floor contraction increased transversus abdominis (TA) increased thickness as demonstrated by ultrasound imaging,[84] however, it does not appear that voluntary pelvic floor contraction results in significantly increased abdominal wall musculature EMG activity.[85] The diaphragm has also been theorized to play a role in spinal stability.[86] The authors encourage clinical exploration in area of pelvic floor and diaphragm training during the early phases of a rehabilitation program and have included a pelvic floor assisted exercise in our prescriptive suggestions.

**Transversus Abdominis/Multifidi recruitment**

Emphasis has been placed on voluntary recruitment of the transversus abdominis (TA) and co-contraction of the multifidi for low back pain for well over a decade. Authors have described various relationships between the TA and the multifidi as well as their influence on low back pain.[87-90] Debate has recently ensued regarding suggested exercises to emphasize recruitment of this musculature. Selective recruitment of the TA and multifidi utilizing "abdominal hollowing" or "drawing in" has been described in the literature and is widely practiced.[89,91] In contrast, the simple "abdominal bracing" exercise is another common exercise which not only emphasizes TA and multifidi recruitment, but has demonstrated increased recruitment of other musculature of the abdominal wall including the internal and external obliques.[90,92] Hodges et al[86] have demonstrated, using an in vivo porcine model, some increased intervertebral stiffness utilizing TA activation by replicating "hollowing". More recently, however, other authors have demonstrated that the increased stiffness from "hollowing" is significantly less than during "abdominal bracing" due to decreased activation of the remainder of the abdominal wall musculature.[92,93] When sudden posterior trunk perturbations are introduced, abdominal bracing yielded significantly greater co-contraction of the trunk musculature, increased trunk stability, and better resistance to lumbar displacement than abdominal hollowing.[94] It also appears that the greater the conscious effort utilized to activate the muscular wall, the greater the decrease in spinal stability.[95] Abdominal hollowing has been shown to cause sufficient inhibition of the erector spinae and other musculature to decrease anterior tilt of pelvis during hip extension.[96] Inhibition of the erector spinae may have specific therapeutic and treatment benefits in addressing potential muscular imbalances, however they are valuable contributors to stable functional movement, which may result in decreased pelvic control if inhibited.

Although co-contraction of the TA and multifidi has been perceived as vital for muscular stabilization of the lumbar spine, their attempted selective activation may decrease anteroposterior trunk stability,[92-95] theoretically placing rotational trunk stability at risk through decreased activation of the external obliques in comparison to abdominal bracing.[90,92] Despite this, utilizing the "hollowing activity" in the early in treatment phases of treatment can provide some symptom relief, kinesthetic awareness, motor control education, and early increased activation of the TA and multifidi during the acute phase. However, once an individual progresses to postures that involve weight bearing, utilization of bracing may be better to enhance multiplanar stability.

Ultimately, conscious efforts towards bracing and/or hollowing do not contribute toward functional stability, rather, focus should be redirected towards addressing specific motor patterns utilizing multiple muscles in order to develop comprehensive spinal stability.[97] Moreover, from a theoretic functional perspective, consciously constraining movement in any region of the body over an extended period of time may alter the demands placed upon numerous other regions of the body. This may be best illustrated with the influence of external fixation, such as the use of a spinal orthosis for reducing pelvic mobility,[98] single segment spinal fusion influencing segmental motion around it,[99] and the increased risk of degeneration above and below the segment of lumbar fusion.[100] Although these examples entail extreme measures of stabilization beyond the level produced consciously by an individual, it serves as a reminder that a balance between mobility and stability is necessary to enable responses to the dynamic demands during movement of the human body.

**Latissimus Dorsi and Thoracolumbar Fascia**

Voluntary activation of the latissimus dorsi may assist with management of low back pain due to its ability to prevent thoracic and upper lumbar "hinging" and may enhance trunk extension under high demands.[5] Latissimus dorsi contribution to tension development in thoracolumbar fascia (TLF) does produce an extension moment at L5/S1, theoretically making it useful in resisting flexion in the most common location for disc herniation. However, this extensor contribution is minimal, with a mere 7 to 11 Nm of torque provided at this level[101] and only another a 30 Nm extensor moment at the sacroiliac joint.[102] Nonetheless, this strong fascial band may serve as a physiologic "back belt".[102] And although it may not independently generate force, this fascial band is strong enough that TLF insertions on the transverse processes of the lumbar vertebrae are capable of transmitting tensile forces sufficient to result in fracture.[103] Based on the fascial relationship of the TA and the latissimus dorsi and the tension developed on the musculature by this fascia, the relationship may provide additional stability to the spine.[5] In addition, the TLF is diffusely innervated by mechanoreceptors and proprioreceptors[104] which may aid in relationship between the neural control and active subsystems described in the Panjabi spinal stability model.

**Stretching and the HLD**

As examined through cadaveric kinematic motion analysis, lumbar spines which exhibited above average ROM were associated with disc degeneration[105,106] and excess flexion and rotation are associated with disc herniation.[36,37] From a protective perspective during the first two phases of rehabilitation, the authors advise against any form of stretching exercise specific to the lumbar spine. The symptomatic presentation of "tight" or shortened erector spinae or quadratus lumborum does not warrant specific flexibility exercises at the risk of increased annular damage. Instead, stretching activities, if utilized at all, may be better used to address tissue in the surrounding regions of the affected segment. Although increased tension of the hip flexors may assist in promoting anterior pelvic tilt and maintaining lumbar lordosis, conversely it may reduce hip extension, therefore careful consideration for stretching of the hip flexors should be made. Addressing additional soft tissue concerns as clinically determined necessary may be relevant, but ensuring protection (avoiding excessive rotation and flexion) of the affected lumbar segment whilst administering these interventions is mandatory.

## A PHASED HLD REHABILITATION PROTOCOL FOR ATHLETES

With an understanding of the anatomy, HLD etiology, spinal stability, HLD healing, and current clinical practices for management of an HLD, the remainder of this clinical commentary will detail the phased rehabilitation protocol proposed herein.

### Phasing the program

In designing a phased rehabilitation program for a HLD in the athlete, the authors have relied heavily on the Panjabi spinal stability model to guide the development of the proposed protocol. Specifically, the authors utilize both the active and neural control systems to direct the therapeutic direction of forces applied to passive systems to help guide the tissue healing process while simultaneously protecting them from further damage. As stated in the literature review, the key passive system target is the outer annulus of the disc. In theory, by focusing on the outer annulus, the therapist can provide a more supportive "wall" which can theoretically be used to provide a idealized environment that promotes homeostasis of NP and also increases nutrient availability to the vertebral endplate in order to reinforce the "ceiling" and the "floor" of the disc. By decreasing the NZ through an improved active system and a more stable passive subsystem (facilitating healing of the annulus and promoting homeostasis of the NP and endplate) the rehabilitation specialist may provide a level of spinal stability that not only resolves the current exacerbation, but ideally prevents future re-occurrence.

Regarding phasing of healing the passive system, the authors have utilized the traditional tissue repair model to reflect healing of the outer annulus. Tissue repair is typically described in three phases, (1) inflammation, (2) proliferation or repair phase, and (3) maturation or remodeling.[107] The duration of each phase varies between individuals, and the phases have some amount of overlap. (1) Inflammation (Day 1 to 6) prepares the tissue for healing, while (2) tissue remodeling occurs during the repair (approximately day 3-20) and (3) remodeling (approximately day 9 and beyond) phases. During the remodeling phase, the scar tissue is modified and shaped into its mature form. As discussed earlier in this clinical commentary, disc herniation is the result of progressive degeneration and often presents in either an acute or subacute form. The subacute form can be thought of as a sudden exacerbation of symptoms within what could be considered a chronic condition that has otherwise gone unnoticed. However, as can be attested by any patient who experiences their first presentation of symptoms from an HLD, the pain, paraesthesias and/or radicular symptoms may present in an acute fashion during a symptomatic HLD episode.

### Four-Phase Rehabilitation Protocol

The authors propose a four phase progression (See Figure 2) associated with phases of tissue healing in addressing the typical lumbar HLD including: Phase I: Non-Rotational/Non-Flexion Phase (Acute Inflammatory Phase), Phase II: Counter rotation/Flexion Phase (Repair Phase), Phase III: Rotational Phase / Power development (Remodeling Phase), and Phase IV: Full return to sport.

## PHASE I: PROTECTIVE PHASE

### (Acute Inflammatory Phase)

During the acute inflammatory phase, the focus is to minimize inflammation by chemical means and

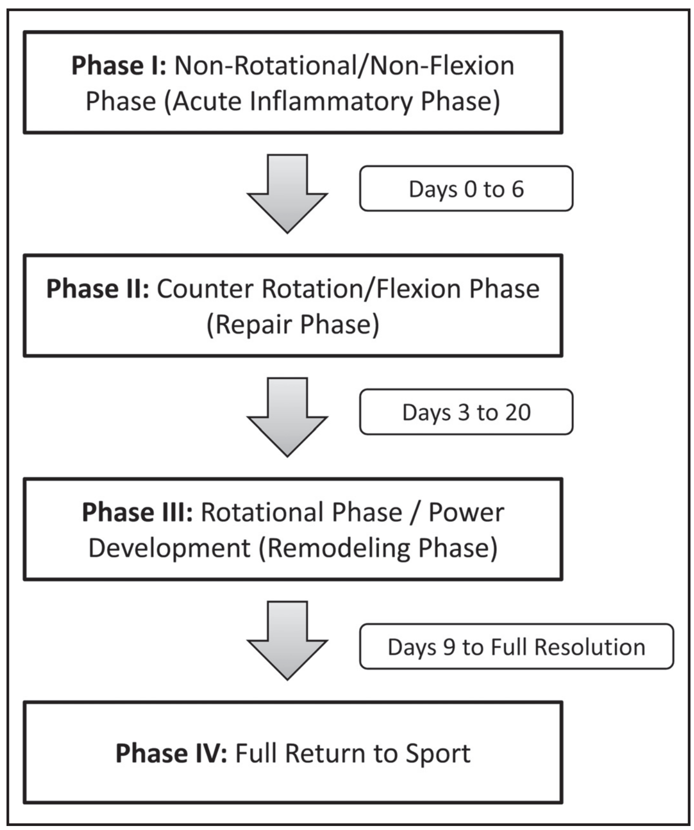


**Figure 2.** *The Four-Phase Lumbar Herniated Disc Rehabilitation Protocol*

also eliminate mechanical stresses imparted upon the disc by utilizing proper body positioning and or movements within pain-free range of motion. Aggressive repeated movements applied to the spine during the inflammation stage may delay healing or cause additional injury. Therefore during phase I of this protocol the objective is to eliminate excessive mechanical stresses on the spinal segment in order to prevent further exacerbation and provide a safe healing environment. Beyond protecting the disc, the goal of this phase is to introduce therapeutic interventions to potentially aid in restoring disc health. Perhaps the cornerstone intervention to the therapeutic treatment of the HLD is the use of Mechanical Diagnosis and Therapy (MDT), commonly known as directional preference, or the McKenzie Method. In determining focus on manual therapy versus MDT emphasis, recent evidence demonstrates that MDT is superior to manipulation during earlier phases,[108] although as stated earlier, there may be clinical value to thoughtfully applied manual therapy interventions. MDT commonly uses repeated movements in the sagittal plane, as well as frontal plane (lateral shift), to evaluate and treat these disruptions. The MDT classification term for posterior and posterior lateral HLD is called a derangement. A derangement can be labeled as reducible or irreducible and is hypothetically based on the presence of the hydrostatic mechanism being intact or not intact within the disc wall. If the herniation is present in a disc where the outer wall is intact then it is reducible and repeated movements would address the mechanical stresses on the disc. If the herniation is present in a disc where the outer wall is not intact then the derangement is irreducible and repeated movements will not improve the pain or symptoms of the patient.[109,110] In asymptomatic individuals, there is a predictive capacity to NP migration in response to positional change,[111,112] however in a symptomatic or degenerative condition, there is less consistency in NP movement or change.[113,114] Nonetheless, the classic MDT thought process of the intervertebral disc as a mobile tissue is key to understanding how to guide directional preference interventions into abolishing the patient's symptoms.[114,110] Despite inconsistency of NP migration in symptomatic and degenerative lumbar discs, the primary cause of herniation is repeated flexion or sustained flexed posturing[35,36,37] and therefore reversal of lumbar HLD symptoms utilizing MDT typically involves preventing flexion through emphasis on maintaining (or possibly even exaggerating) lumbar lordosis during symptomatic periods and utilizing repeated active and passive extension aimed at symptom resolution[115] and therefore will serve as the focus of phase I of this protocol. Further detail addressing anterior disc derangement and the "lateral shift" and variations can be obtained through more specific MDT evaluation and treatment techniques beyond the scope of this commentary.

This phase will focus on motion in the sagittal plane in an effort to help control symptoms during the acute phase. Emphasis on stabilization and hip extensor training serve as the basis for emphasizing the active and neural control subsystems of the Panjabi stabilization model and in theory will be complimentary to addressing the passive subsystem addressed through MDT protocols. Early use of stabilization training exercises has demonstrated improvements in symptom management for the lumbar HLD patient.[67] In addition, addressing gluteal weakness and/or inhibition as discussed in Janda's Pelvic Crossed Syndrome may provide hip strength and endurance useful for developing a protective "hip hinging" strategy. Hip hinging involves developing a motor strategy in which flexion of the torso occurs primarily through flexing at the hips rather than throughout the lumbar spine. Flexing at the hips promotes maintenance of lumbar lordosis by means of a slight anterior pelvic tilt throughout the range of motion of forward bending.[116] From the authors clinical experience many athletes even at the elite level lack the capacity to dissociate hip flexion from lumbar flexion whether due to lack of motor control or lack of available ROM, thus potentially leading to their training methods contributing to the cause of their HLD. Therefore during this relative "down time" for the athlete it is important to take the opportunity re-educate the athlete in the fundamental movement patterns commonly used during their conditioning activities.

## PHASE II: COUNTER ROTATION/FLEXION PHASE

### (Repair Phase)

Continuing the paradigm of soft tissue healing as applied to outer annulus repair, exercise intervention must transition into controlled movements that positively affect the healing tissues. This must be performed in a manner that is protective of the spinal segment, but adequately provides tension in the line of collagen fibers in order to stimulate fibroblast repair of the collagen matrix.[53] Early controlled movement may also assist with healing of the endplate, as repetitive micromovement has been shown to stimulate fracture healing.[117] As previously discussed, a combination and flexion and rotation has been implicated as injury mechanisms in disc herniations,[37] but both components are necessary for return to normal function of the intervertebral disc during human movement. This phase introduces exercises that are loaded in a way that utilizes isometric contractions to resist frontal and transverse planes (rotation) movement. To produce this effect, the authors suggest the use of unilateral loaded exercises. Lumbar rotation has been shown to be coupled with lumbar lateral flexion,[118] and it has been proposed that that muscular contraction may have a greater role in this coupling behavior than passive structures.[119] Based on the increased muscular role, the authors speculate that isometric resistance to lateral flexion may produce a theoretically "safer", or at the very least, less symptomatic, challenge to the oblique orientation of the annulus in resisting rotation rather than through full rotation itself during this phase. The interventions contained in this phase are chosen in order to develop tension forces on the annulus that gradually reintroduce flexion forces and resist rotation through compound movements and controlled flexion emphasis during exercises.

## PHASE III: ROTATIONAL PHASE / POWER DEVELOPMENT

### (Remodeling Phase)

The remodeling phase is vital to fully engage the functional design of lumbar disc and absolutely required for successful return to sport participation. In this phase, full integration of transverse plane movement must occur. Continued progression of movement and loads in dynamic activities will aid in the alignment, organization, and cross-linking of collagen fibers.[53,54] Progress to full dynamic rotation rather than simple isometric tensile forces as were utilized in the counter rotation phase is needed in order to fully stress the entire range of the collagen fibers and restore normal intervertebral disc function. Clinically, the introduction of dynamic rotation may result in increased HLD exacerbation symptoms. Therefore slow and careful progression, and if necessary, regression between phases must be made as deemed clinically necessary. Mechanically, the fiber orientation of the lamellae during rotation may produce a conjunct compressive force that can assist with nutrient delivery to the NP and inner annulus, assisting in healing much in the same way that articular cartilage responds to repeated cycling of compression and distraction.[48,49] In addition, as discussed by Adams, controlled rotation may aid in reducing excessive scar tissue formation within the annulus.[26] Expanding this even further, reducing scar tissue formation may prevent annular cell death and allow adaptive cell reorientation of the annulus to occur.[120] Abbott et al demonstrated in human annular tissue that restriction of adaptive reorientation of annular cells, such as being restricted by Type 1 collagen scar tissue, appears to play a role in stretch-induced cell death in the annulus.[120] Along this spectrum, power development using lower loads and exercises which emphasize mechanics that are protective of the HLD should be introduced in order to prepare the athletes for the rate of force development necessary for their sport and their strength and conditioning programs.

## PHASE IV: FULL RETURN TO SPORT

Throughout the entirety of the rehabilitation process, some attempt towards sport specific technique and conditioning should be maintained within the postural guidelines and loading guidelines suggested above. Clearly this must be reasonable and the athlete needs to be far enough out of the acute phase to participate in non-sport activities of daily living in order to do so, but to completely shut an athlete down through the entirety of an exacerbated HLD may result in significant deconditioning, which has been associated with increased risk of injury.[121] The athlete must be able to freely move in all three planes of motion with adequate mobility, motor control, efficiency, and power. In the transition from Phase III to Phase IV, the athlete must be participating in every facet of their respective sport to some degree. This must be graded appropriately, but all of the athlete's specific movement skills must be occurring at this time. Gradual decrease in emphasis on abdominal bracing should be performed with emphasis switching to stable and controlled mobility throughout the ROM demands of sport activity. However, abdominal bracing should still be reinforced during strength training, in particular with heavier lifting.

Postural education should be coordinated with the athlete's coach in order to determine the appropriate balance between a protective posture and optimal sport performance. In most sports, a neutral spine posture will be beneficial, but in some sports such as rowing or cycling, a true neutral spine position is not possible. In these cases, inadequate hip mobility or lack of thoracolumbar extension may compound the risk placed on their lumbar discs in their sport position. Therefore, the best attempt toward improving hip mobility and thoracolumbar extension should be made, but recognize that years of sport specific tissue adaptation may prevent the athlete from achieving the "optimal" neutral spine in their sport position. In addition, some sports, such as gymnastics, wrestling, or mixed martial arts (MMA), require extreme concentric forces generated at, or near, end ranges of flexion, in these cases, avoid additional training loads in these positions and leave these ranges for sport participation. Provide education on maximizing muscular stiffness with simple cues such as "keep tight" when the athlete works in these ranges, but be aware that too much conscious effort from the athlete on spinal stability at these ranges may be detrimental to sport performance. Seek additional sports specific return to sport protocols as needed.

## CONCLUSION

Successful outcomes in complex clinical presentations are never guaranteed. However, systematic approaches emphasizing biomechanical principles at least give a starting point from which to attempt to best implement evidenced based strategies with the goal of the best possible outcome within the constraint of a problem. Carefully constructed staged rehabilitation protocols may assist the clinician in challenging thinking regarding the necessity of regaining full, functional movement in athletes after a HLD. The authors hope that this clinical commentary provokes thought, provides ideas, and helps guide future advancement in the area of conservative treatment of the athlete with an HLD.

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## APPENDIX 1: DESCRIPTION OF SUGGESTED EXERCISES BY PHASES

### Disclaimer

This appendix of exercise descriptions is intended to serve as a general overview of exercise suggestions for each defined phase but requires a far greater understanding of each exercise than described below. Furthermore, no guidance is provided regarding dosing of each exercise. It is assumed that clinical experience and knowledge will be applied to determine tolerance and deficits in each patient in the deciding dosage and whether an exercise is appropriate for the individual patient.

## PHASE I: PROTECTIVE PHASE

### (Acute Inflammatory Phase)

### Directional Preference Progression (MDT/ McKenzie Method)

Utilized in accordance to the MDT diagnosis and prescription. This includes addressing a lateral shift prior to emphasis on extension. A good clinical response to extension using the "prone press up" has been demonstrated in the LDH population[122,123] and unspecific LBP population.[115] Recent evidence exists for an improved response to MDT over manipulation in the presence of peripheralization or centralization.[108]

**Figure 3a.** *Prone Press Up - Bottom*

**Figure 3b.** *Prone Press Up - Top*

### Transversus abdominis hollowing and bracing exercises

Numerous articles published in the literature have addressed initiation and progression of transversus abdominis (TA) exercises, we defer to Hides, Jull, and Richardson for specifics regarding individual exercises.[88] Instead we wish to highlight key points and differentiation between the two exercises.

### Abdominal Hollowing

As discussed in Part I of this article, there is evidence for improved symptom management of LBP using the abdominal hollowing or abdominal drawing-in exercise.[87-90] However, as discussed by Grenier and McGill, hollowing may be less effective in spinal stabilization than bracing due to the absence of the external oblique activation.[11] Nonetheless, abdominal hollowing assists in symptom management, kinesthetic awareness, motor control education, and voluntary forced activation of the TA and multifidi, which are extremely valuable during the protective phase of rehabilitation in the absence of significant external demands. It is easy to progress the difficulty of the practice of abdominal hollowing by using varied postures such as quadruped, tall-kneeling, and half-kneeling. The patient should be educated to about future progression to abdominal bracing and at that point to switch from hollowing to bracing during weight bearing activity.

### Abdominal bracing

Abdominal bracing reinforces the skill of utilizing the entire abdominal wall (TA and obliques) to stabilize the spine. McGill provides an excellent educational procedure for teaching an individual to brace.[5] Demonstrate to the athlete the concept of isometrically bracing a joint with the example using the elbow joint. Ask the athlete to flex their elbow joint and isometrically contract both the flexors and extensors. This should allow the athlete both kinesthetically and with palpation, to identify how the muscles are stabilizing the elbow joint thereby preventing movement.

- Have the athlete visualize the same concept of using their abdominal wall to produce the same response in the muscles surrounding their spine. An anecdote familiar to the athlete may be to imagine how they would prepare for a strike to the stomach, which is exactly the technique they need to perform abdominal bracing.
- Have the athlete demonstrate the concept without hollowing or expanding their abdomen, and palpate for rigidity around the abdomen and spinal extensors.
- Once the athlete is able to perform the skill in standing, have them apply this same concept to all of the prescribed exercise interventions. The goal is to prepare them to apply the same concept to all of their activities and exercise.

## Hooklying hollowing with foam roller adduction and pelvic floor recruitment

This is a valuable exercise that the authors have found useful for early neuromuscular re-education of the TA, multifidi, and the pelvic floor. Although the increased intra-abdominal pressure associated with contractions may be symptomatic for some, in general this exercise is tolerated well even on within the first 24 hours of discogenic symptomatic presentation. The patient assumes a hooklying position with a foam roller or towel roll of at least 3" in diameter between their knees. Have the patient perform the hollow/draw-in procedure while simultaneously gently adducting the thighs to squeeze the foam roller and attempting to perform a Kegel exercise for pelvic floor recruitment. Begin with 5 second holds for 5 repetitions and progress up to 30 second holds. This cognitive, proprioceptive, and motor control activity will require significant cueing and reminders to perform, but in theory due to the early neuromuscular demands may assist with later progression and allow for early proprioceptive and kinesthetic awareness of several of the muscles which appear develop dysfunction.

## Hip Hinging in Standing

The waiter's bow is an important precursor exercise used to teach an individual how to "hip hinge". A neutral spine position requires that a degree of lumbar lordosis be maintained in order to neutralize the curvature of the spine.[124] As discussed in Part I, flexing at the hips promotes better maintenance of a lumbar lordosis in a neutral spine position throughout the range of motion.[116] While standing upright, place a hand on the stomach and the other on the low back. Provide the trainee instruction regarding maintaining a neutral spine and abdominal bracing. Alternatively or in conjunction, utilizing the metaphor of the ASIS as "headlights" for pelvic control can be beneficial. Once the hinging motion is achieved, the addition of the "gluteal pulse" during hip extension can be taught. Gluteal pulse involves consciously contracting the gluteals during hip extension starting at the end of hip flexion and

**Figure 4a.** *Hip Hinging in Standing - Start/Stop*

**Figure 4b.** *Hip Hinging in Standing - Hip Flexion/Middle*

peaking with maximal tension at the terminal point of hip extension resulting in an "explosive" (increased velocity) forward drive of hips without hyperextending lumbar spine or the knees. Since there is synergy between hip extension and knee extension,[125] it may be helpful to cue knee extension with the gluteal pulse in order to enhance coordination during the technique.

## Sidelying abduction

As previously discussed, decreased hip abduction strength and hip external rotation, has been demonstrated as a predictors of back and lower extremity injury.[80,81] The importance of the role of the hip abductors, in particular the gluteus medius in pelvic stability is well known.[126]Clinical evaluation of strength and endurance deficits with appropriate dosing to address weakness and fatigue may provide a protective mechanism for the lumbar spine by preventing excess motion through the pelvis. Various exercises have been proposed for improving hip abduction. Of these, sidelying hip abduction has most consistently demonstrated the greatest recruitment of the gluteus medius.[127-129]

## Bridging

Starting in a hooklying position, place the heels approximately thigh length from the gluteals. Perform a minimal posterior pelvic tilt to provide for a neutral spine position and brace the entire abdominal and gluteal musculature. Perform the bridge by driving force into the heels, emphasizing gluteal activation over hamstring activation while performing the motion. Maintain abdominal bracing throughout the movement and end position.

**Figure 5a.** *Bilateral Bridge - Top Position*

**Figure 5b.** *Unilateral Bridge - Top Position*

In addition, utilizing a foam roller or small ball between the knees may provide additional pelvic floor and adductor involvement and a resistance band outside of the knees provides additional loading of the abductors. The single leg progression introduces some counter-rotation and additional lateral stability components, so be aware of additional symptom provocation, progressing as tolerated.

**Figure 6a.** *Weighted Bridge / Hip Thrust - Start*

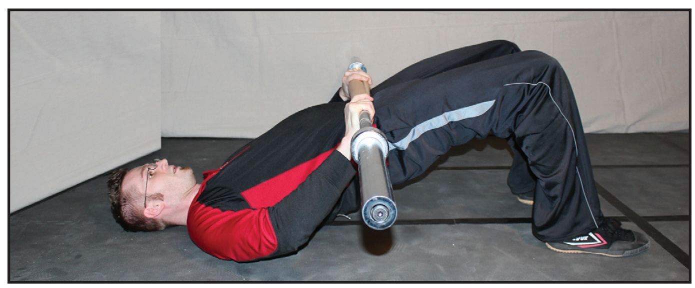

**Figure 6b.** *Weighted Bridge / Hip Thrust - End*

An optional progression involves the addition of resistance to hip extension. Manual based PNF progressions could provide controlled introduction to resistance. Additional resistance progression can include the use of a padded barbell (sufficiently padded to protect the pelvis and genitourinary region from significant compression). Note that the presence of SI joint dysfunction may provoke symptoms due to the approximation and compression of both innominates through this form of loading, making this an inappropriate selection for some patents.

## Quadruped bracing

Utilizing a 4-point position in quadruped, the athlete must move between the extremes of lumbar lordosis and lumbar kyphosis in order to identify and be instructed on a

**Figure 7a.** *Quadruped - Lordosis*

**Figure 7b.** *Quadruped - Neutral Spine*

neutral spine and pelvic position which is then braced and held isometrically. Additional challenges in this position can include movements of the upper or lower extremities, which add mild stabilization demands against rotation.

## Plank progressions

Numerous plank variations and progressions exist. A beginning level will vary from a kneeling position (half)

**Figure 8a.** *Traditional Plank*

**Figure 8b.** *Ball Plank*

**Figure 8c.** *Suspended Plank*

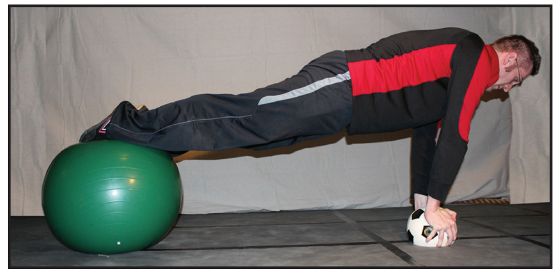

**Figure 8d.** *2-Point Ball Plank*

**Figure 8e.** *Side Plank - Advanced*

plank to a full plank on the floor depending on tolerance. Emphasis on incorporating a neutral spine, abdominal bracing, gluteal activation, and latissimus dorsi activation (see further discussion on this muscle in the lat pull-down summary) promote recruitment of all key voluntary and involuntary active spinal stabilizers. Progression to a single unstable surface for the upper or lower extremity in order to increase stabilization demands can be added. Maximal challenge, if warranted within the demands of athlete's sport, can be obtained with two unstable surfaces, the introduction of perturbations, and/or voluntary induced movement while maintaining a stabilized neutral spine. An excellent high level plank exercise is the "Stir the Pot" stability ball exercise discussed by McGill. This exercise consists of perform an elbow based plank on the stability ball, bracing and maintaining a neutral spine, and performing clockwise and counterclockwise rotations through the upper extremity onto the ball.

## Pushup Progression

Similar to the plank progression, first transition from a kneeling position to a full pushup position. Emphasis is placed on abdominal bracing and gluteal activation throughout the entire motion. Progress toward unstable surfaces in a similar manner as planks, utilizing unstable surfaces in either upper or lower extremity positions, or at the highest level on two unstable surfaces.

**Figure 9a.** *Kneeling Pushup - Start*

**Figure 9b.** *Kneeling Pushup - End*

**Figure 9c.** *Full Pushup - Start*

**Figure 9d.** *Full Pushup - End*

**Figure 9e.** *Suspended Pushup - Start*

**Figure 9f.** *Suspended Pushup - End*

## Lunge/Split Squat progressions

Lunges are typically easier to instruct by having the patient initially perform them in a stationary method,

**Figure 10a.** *Stationary Lunge - Top*

**Figure 10b.** *Stationary Lunge - Bottom*

**Figure 10c.** *Bilateral Weighted Lunge - Top*

**Figure 10d.** *Bilateral Weighted Lunge - Bottom*


**Figure 10e.** *Barbell Lunge/Split Squat - Top*


**Figure 10f.** *Barbell Lunge/Split Squat - Bottom*

using the split squat technique rather than with movement such as stepping into a lunge. A stationary position also makes it easier to educate regarding proper distancing between the feet and avoids excessive stabilization demands in movement during acute phases. Do not discount the use of an upper extremity contact with a sturdy object during familiarization in the acute phase. As with all exercises, begin with abdominal bracing and maintain throughout and include management of excessive anterior or posterior pelvic tilt. Emphasize lowering the body back and down and delivering force into the heel of the front foot. Progression to moving lunges only once adequate spinal and pelvic control is demonstrated, starting first with a backward step to reinforce posture during movement and loading.

Typically it is not appropriate to load lunges during the acute phase, however, loading should be encouraged during Phases II and III in order to assist with tissue healing and remodeling. Loaded lunges may provide a position in which a neutral spine is more easily maintained while still providing progressively increased linear compressive loads, which may aid in lumbar disc healing. Proceed to load as tolerated, loading bilaterally to reduce counter rotation/lateral flexion demands. As the athlete progresses to higher loads, the elevated foot split squat provides high loads without the higher hip flexion requirements of bilateral squatting.

**Lateral Squat Stepping / Resisted Abduction (Monster Walk)**

This exercise introduces some frontal plane movements. It is commonly recognized as a version of the "monster walk" and offers an early opportunity to introduce increase abduction movement in a position that is frequently asymptomatic for the HLD patient. Emphasis remains on abdominal bracing and control of pelvic and spinal position.

**Figure 11a.** *Lateral Squat Stepping - Resisted Abduction - Start*

**Figure 11b.** *Lateral Squat Stepping - Resisted Abduction - Step*

**Upper Extremity Pull Down (Latissimus Pull Down)**

The latissimus pull down exercise is a simple early exercise which emphasizes the activity of the latissimus dorsi. With a slight amount of extension throughout the spine in order to pretension the latissimus dorsi and to decrease the amount of effort it takes to prevent trunk flexion, brace and maintain the position throughout the exercise. The load should never be so great as to move the athlete out of their starting position and prevent their ability to maintain a braced position. The goal is to progress towards pull-ups as early as possible.

**Figure 12a.** *Lat Pull Down - Top*

**Figure 12b.** *Lat Pull Down - Bottom*

## Inverted row progressions

Recent evidence has demonstrated that of typical rowing exercises utilized, the inverted row demonstrates the lowest spinal load with significant upper back musculature demands.[130] Although this example utilizes suspension device, a Smith machine or secured barbell can be similarly utilized. A suspension device may add a degree of multiplanar instability and challenge to the core in comparison to a straight bar and provide a free range of motion at the wrist and elbow. Emphasis should be on abdominal bracing and gluteal activation throughout the entire motion. Starting the movement with a supinated hand (underhand) position can lessen the early demands on the upper back by allowing greater contribution of the biceps to pulling movement.[131,132] A progression of this exercise is three fold: One switch the hand to a pronated (overhand), two, increase the angle in which the athlete is positioned , and three, add resistance to the upper body through weight plates or a weighted vest.

**Figure 13a.** *Suspension Inverted Row - Angled Incline - Bottom*

**Figure 13b.** *Suspension Inverted Row - Angled Incline - Top*

**Figure 13c.** *Suspension Inverted Row - Parallel Incline - Bottom*

**Figure 13d.** *Suspension Inverted Row - Parallel Incline - Top*

## Pull-up/chin-up progressions

A pull-up is defined as a pronated grip on the bar, while a chin-up is a supinated grip. The pull-up is challenging to the entire body, including the core. Recent EMG studies demonstrated that pull-ups, chin-ups, and the Perfect Pull-Up™ have similar levels of latissimus dorsi recruitment, although the pull-up appears to have additional recruitment of the lower trapezius,[132] which plays a role in thoracic extension. As a result, it may be beneficial to progress toward a full pull-up. However, due to additional contribution of the biceps,[132] the chin-up may be an easier starting point for some. Although a full chin-up or pull-up may not seem possible for some individuals, the use of high-density resistance bands or machine assistance can be a starting place. With an appropriate progression including eccentrics and assistance, most can achieve some level of success in this exercise. An excellent resource for pull-up progressions is available in *Michael Boyle's Functional Training for Sports*.[133]

**Figure 14a.** *Pull-up - Hang Position*

**Figure 15a.** *Suspension Assisted Squat - Top*

**Figure 14b.** *Pull-up - Top Position*

**Figure 15b.** *Suspension Assisted Squat - Bottom*

## PHASE II: COUNTER ROTATION/FLEXION PHASE

### (Repair Phase)

#### Suspension Device Assisted Squat

Utilizing a suspension-based device (TRX® Suspension Trainer, LifelineUSA®, Jungle Gym, heavy resistance band, heavy rope, etc.) to unload and control the decent of a bilateral squat may be beneficial for assisting in control of hip/lumbar flexion and their related compressive loads. In addition, the suspension device helps to reinforce the idea of "sitting back" and down to increase emphasis on the gluteals, thus doubling as an educational tool. As this is the first bilateral squatting activity to be reintroduced to the athlete, now is the time to educate the athlete how to flex primarily at the hips rather than flexing at the lumbar spine, or what is commonly known as the "the hip hinge" during the squat. Flexing at the hips promotes better maintenance of a neutral spine position throughout the range of motion.[116] Progression for the squat should start with the feet slightly wider than shoulder width. This width can be increased even further to decrease the degree of spinal flexion by increasing the amount of hip flexion utilized to complete the movement.[134] Emphasize maintaining a neutral spine, abdominal bracing, gluteal activation, and latissimus dorsi activation. Instruct the athlete to sit back into the squat utilizing the suspension device to offload and control the decent. During the ascent, instruct the athlete to have the chest rise first, but at the same time forcefully activate the gluteals to drive the hips forward during hip extension, maximizing posterior chain activation. With good tolerance and technique, instruct the athlete to gradually utilize the suspension device less, potentially switch to single hand assistance, so long as rotation is not introduced into the squat.

### Bodyweight Squatting with Latissimus Activation

Bodyweight squatting with the involvement of latissimus dorsi may assist with developing synergistic tension with the abdominal musculature on the surrounding fascia as described previously. Cue the athlete to consciously increase tension in the latissimus dorsi using hand/arm positioning similar to the image above or simply educate them on developing voluntary tension of the latissimus dorsi in any preferable arm position. Throughout the motion emphasize maintaining a neutral spine, abdominal bracing, gluteal activation, and latissimus dorsi activation. Instruct the athlete to sit back into the squat with good control of the spine. During the ascent, instruct the athlete to have the chest rise first, but at the same time forcefully activate the gluteals to drive the hips forward during hip extension maximizing posterior chain activation.

**Figure 16a.** *Bodyweight Squat - Top*

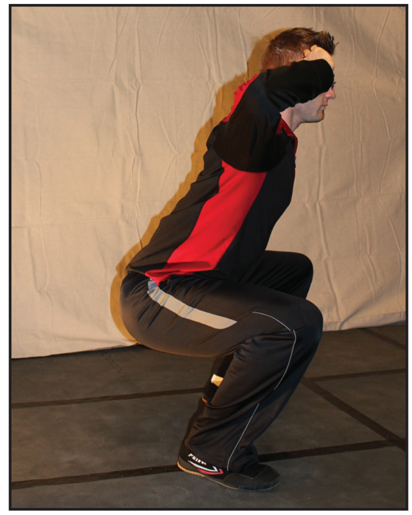

**Figure 16b.** *Bodyweight Squat - Bottom*

### Anterior Loaded Squat (Aka: Goblet squat)

Due to a shortened lever, the use of an anterior loaded squat typically positions the load in a position in which a neutral spine is more easily maintained, while still providing progressively increased linear compressive loads, which may aid in disc healing. Use of a kettlebell or dumbbell rather than a traditional front squat using a bar is less technically challenging to many athletes.

**Figure 17a.** *Anterior Loaded Squat - Top*

**Figure 17b.** *Anterior Loaded Squat - Bottom*

### Turkish getup

The Turkish getup is an incredibly challenging total body movement that demands stability throughout the body. The kettlebell does increase the challenge of the exercise due to the position of the weight away from the body, and a dumbbell is also acceptable. The cornerstone of the exercise movement is emphasis on spinal stability. Education of the technique should begin without a weight. The wrist must be held in a neutral position, as if to deliver a punch, throughout the entire movement. Keep your eyes on the weight throughout the movement.

**Figure 18a.** *Turkish Getup - Bottom*

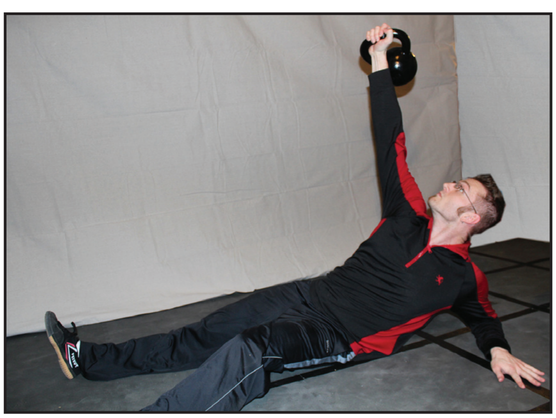

**Figure 18b.** *Turkish Getup - Hip and Trunk Drive*

1. Laying on your back, use both arms to get the weight to chest position, fully extend the right wrist and arm.
2. Retract the right scapula to stabilize the shoulder girdle and voluntarily recruit the latissimus dorsi drawing the humeral head tight into the glenoid.
3. Bend right knee to bring the right foot close to the right gluteal while keeping the arm locked in position
4. Drive the right hip up by pushing off the heel on the right side while keeping your core braced and shoulder locked and moving skyward .
5. Sit up with assistance of left arm on floor to side.

**Figure 18c.** *Turkish Getup - Lunge Position*

**Figure 18d.** *Turkish Getup - Top*

6. Keeping your eyes skyward following the weight, pull left leg back between right leg and left arm and position forefoot and knee on floor behind right foot and left hand into a lunge position.

7. While still looking at the weight, rise into a lunge and progress to full standing position. The arm should be in line with the ear with the entire body tense in securing the weight.

8. To return back to the floor, the movement is reversed beginning at step 7. It is important to maintain total body tension throughout the entire reversal movement including keeping the humeral head tight in the glenoid.

### Unilateral side lift (Suitcase lift)

Loading the weight unilaterally to the side requires significant demands for contralateral lateral flexion and counter rotation stabilization at the spine in order to maintain a neutral position.[135] Position the weight at a height which will yield between 40° and 60° of hip flexion. Have the athlete brace their abdominals, grab the weight, and emphasize driving the hips forward using a strong gluteal contraction while maintaining a neutral spine. Reinforce "hip hinge" rather than flexing at the lumbar spine.

### Curl-up

Concerns with the compressive loads induced by abdominal flexion are well warranted.[35,37] However, normal human function requires some degree of flexion and rectus abdominis activation. Therefore, it is important to safely and progressively reintroduce the motion to the athlete. The curl-up has been demonstrated by Juker et al to demonstrate the greatest balance between rectus abdominus and the abdominal wall (obliques and transversus abdominis) and while minimizing lumbar compressive and shear forces.[136] The curl-up is performed in hooklying position and requires that the shoulder blades just barely clear the floor to complete the exercise. Progress to the stability ball curl-ups once tolerated.

**Figure 19a.** *Unilateral Side Lift - Bottom*

**Figure 19b.** *Unilateral Side Lift - Top*

### Stability ball curl-ups

Stability ball curl-ups assist in decreasing the degree of compressive forces induced from flexion by beginning

**Figure 20a.** *Stability Ball Curl-up - Start*

**Figure 20b.** *Stability Ball Curl-up - Finish*

the movement in an extended position and then moving to a flexed position just beyond neutral. In addition, the unstable environment appears to increase abdominal wall activity.[137]

### Kettlebell Deadlift

The deadlift requires significant extensor contribution of the entire posterior chain[138] and again, presents an opportunity to educate the athlete how to "hip hinge" rather than flexing at the lumbar spine. Utilizing a kettlebell or dumbbell from an elevated surface and then progressing to the floor provides a way to progressively introduce this movement. The importance of bracing and voluntary activation of that latissimus dorsi in overall spinal stiffness is paramount, begin with the lightest load possible and evaluate the athlete's subjective perception of and ability to maintain a rigid spinal posture. This rigidity is not to be let go until the hands are no longer on the weight. The lift is initiated with hip drive but the chest must lead the direction of the movement, thus driving the hips under the chest, producing the "hip hinge" effect.

**Figure 21a.** *Kettlebell Deadlift - Bottom*

**Figure 21b.** *Kettlebell Deadlift - Top*

### Trap Bar/Hex Bar Deadlift

The mechanics of the kettlebell deadlift carry over, for the most part, to the trap bar/hex bar deadlift. The trap bar deadlift is somewhat of a hybrid between a squat and a deadlift, with a subjective increased perceived effort through the quadriceps as compared to mainly posterior chain activation. In the authors experience and historically in the powerlifting community, many athletes


**Figure 22a.** *Trap Bar/Hex Bar Elevated Deadlift - Bottom*


**Figure 22b.** *Trap Bar/Hex Bar Elevated Deadlift - Top*

**Figure 22c.** *Trap Bar/Hex Bar Deadlift - Bottom*

**Figure 22d.** *Trap Bar/Hex Bar Deadlift - Top*

have reported decreased back pain from utilizing the trap bar. This may in part be due to increased quadricep involvement combined with a decreased hip flexion angle obtained by utilizing the taller grips of the bar and/or lifting the weight from boxes, all of which appear to yield an increased capacity to lift heavier loads utilizing less lumbar flexion. In addition, by loading weight to the side, spinal compressive loads are increased more than shearing forces.[136]One common error that is important to prevent is keeping the pelvis from moving too far forward. This occurs because the trapbar does not provide a physical block to the pelvis in the way a standard straight bar does during the fully extended position of the deadlift (the lockout). Therefore, it is very easy for the athlete to excessively hyperextend the lumbar spine, in particular as the weight gets heavier. Therefore, observe the technique closely and provide cueing to prevent this behavior.

### Single Leg Deadlift

The single leg deadlift (straight leg or bent knee depending on emphasis on hamstrings) provides an excellent muscular activation profile for increased abductor stability, resisting counter rotation, and also is challenging to balance.[127] Recent literature has demonstrated some value in balance base training in the chronic LBP population.[139] In general, this exercise is most controlled with the weight on elevated surface. Fundamental bracing, use of the hip hinge technique, and conscious awareness of posture remains a requirement.

**Figure 23a.** *Single Leg Deadlift - Top*

**Figure 23b.** *Single Leg Deadlift - Grab*

**Figure 23c.** *Single Leg Deadlift - Lift*

## Single leg squat

Single leg squats can vary in difficulty, with parallel single leg squats being one of the most challenging lower body exercises. For most, a 75° angle squat is a good target for this exercise, providing sufficient balance and stability challenge and excellent unilateral loading of all of the gluteal muscles.[140] Stability throughout the hip and the spine is significantly challenged. Progression should begin first with 10-15° heel touches utilizing a braced neutral spine position and then gradually moving up to approximately a 75° angle. As the exercise is progressed beyond 75°, the challenge to maintain a neutral spine increases, and at

**Figure 24a.** *Single Leg Squat - Top*

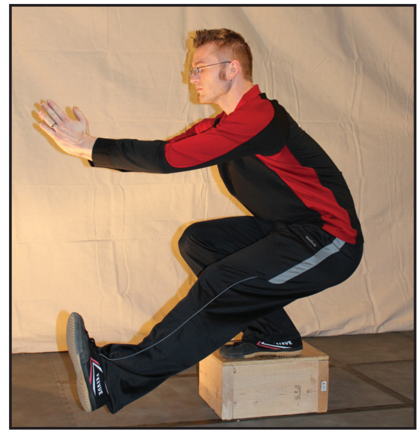

**Figure 24b.** *Single Leg Squat - Bottom*

a certain point some lumbar flexion will occur. Therefore, progression beyond this level is dependent on the athlete's sport requirements or motivation to pursue the challenge safely.

## Bottoms-up Kettlebell Carry

Carrying the kettlebell in a "bottoms-up" position while walking is typically subjectively perceived as a challenging exercise. However, recent analysis of the bottoms-up kettlebell carry has demonstrated a lower activation profile than would be expected from this activity.[135] None the less, there are conservative, yet significantly increased spinal compression and shear forces demonstrated in the bottoms-up position when compared to a normal position carry,[135] which may provide a safe stimulus to assist

**Figure 25.** *Bottoms Up Kettlebell Carry*

with annular healing during this phase and may be a good transitional activity to the next rehabilitation phase as the disc remodels.

## PHASE III: ROTATIONAL PHASE / POWER DEVELOPMENT

### (Remodeling Phase)

### Lunge with a twist

As previously discussed, there may be some evidence that supports the introduction of rotation to affect the intervertebral disc and assist in proper scar formation in the annulus[26] while providing force to assist in guiding fiber reorientation, and the ability to withstand rotationally developed compressive forces which are a part of normal spinal function. The lunge with a twist is an easy to grade and modify method of introducing rotation. With the ipsilateral flexion of the hip, the lumbar spine is given a fixed point in which ipsilateral rotation can be introduced through hip/trunk dissociation. The balance between stability and mobility must be carefully weighed and discussed, but ultimately, successful return to sport will require the ability develop fluid, controlled rotation movements without conscious effort.

**Figure 26a.** *Lunge with a Twist - Same Side Rotation - Top*

**Figure 26b.** *Lunge with a Twist - Same Side Rotation - Bottom*

### Supine Stability Ball Twists (Russian twists)

A stability ball does not provide the degree of hip and lumbar dissociation as the lunge with a twist due to being performed in a non-weight bearing position of the spine,

**Figure 27a.** *Stability Ball Twist - A*

**Figure 27b.** *Stability Ball Twist - B*

**Figure 27c.** *Stability Ball Twist - Weighted - A*

**Figure 27d.** *Stability Ball Twist - Weighted - B*

with the hip in an extended position, providing an environment in which progressive loading can be introduced in trunk rotation with some protection of the lumbar spine. The hips and trunk should be maintained in a straight line parallel to the floor. Begin in smaller arcs of rotation before performing full 90° rotations.

## Chops and Lifts

The energy transfer from the ground through functional synergies of the lower extremity to the upper extremity through the core is a common requirement in many athletic skills. Chops and lifts provide a good general analog to this movement pattern and are valuable return-to-play exercises that allow progressive introduction of load by demanding concurrent rotation and force transfer from the ground.

**Figure 28a.** *Band Chop - Top*

**Figure 28b.** *Band Chop - Bottom*

**Figure 28c.** *Band Lift - Bottom*

**Figure 28d.** *Band Lift - Top*

## Kettlebell swings

The kettlebell swing provides an opportunity to begin power development earlier than barbell-based exercises. In comparison to barbell exercises, kettlebell power exercises are performed with a lower weight, decreased hip flexion, and, particularly beneficial to the HLD patient with a posteriorly migrated NP, increased posterior vertebral shearing compared to anterior shearing.[135] Jay et al recently demonstrated the use of kettlebell exercises in a work hardening program with significant improvements in low back pain and improved torso strength.[141] In addition, McGill demonstrated that spinal loads were quite conservative with a 16kg kettlebell (~35 lbs) weighing in at under 3200N of compressive force.[135]

**Figure 29a.** *Two Handed Kettlebell Swing - Bottom*

**Figure 29b.** *Two Handed Kettlebell Swing - Top*

**Figure 29c.** *Single Handed Kettlebell Swing - Bottom*

**Figure 29d.** *Single Handed Kettlebell Swing - Top*

Key points to the kettlebell swing, in particular with an HLD patient, is cueing for significant bracing for spinal stability throughout, some level of gluteal activation throughout, emphasis on the "hip hinge", voluntary latissimus dorsi recruitment to reinforce the abdominal wall, and powerful hip extension. In agreement with the Russian Kettlebell Challenge (RKC) standard, the kettlebell should swing no higher than eye height. This height may provide a more controlled range of movement preventing excessive spinal extension and more control with lowering the kettlebell in comparison to methods of swinging overhead. Progression should be performed from two hand swings to one hand swings, but do not discontinue the two hand swing. Additional information regarding the RKC method of kettlebell swings and other fundamental swings can be obtained in Pavel Tsatsouline's *Enter the Kettlebell*.[142] An important consideration regarding kettlebell swings is that the weight of the kettlebell needs to be sufficient enough as to not allow the use of the arms to drive the swing but instead force use of the hips to drive the swing. This is one of the few scenarios in which being too conservative on the load may be detrimental to the benefits of the exercise.

### KB snatch

Once the kettlebell swing is mastered with adequate weight and good technique, the kettlebell snatch provides increased muscular activation of the core in comparison to the kettlebell swing with similar compressive and kinetic results as the swing.[135] The kettlebell snatch has higher technical demands than many of the exercises provided here and instruction on proper form is beyond the scope of this article. Once again, *Enter the Kettlebell*[142] provides an excellent overview of the technique.

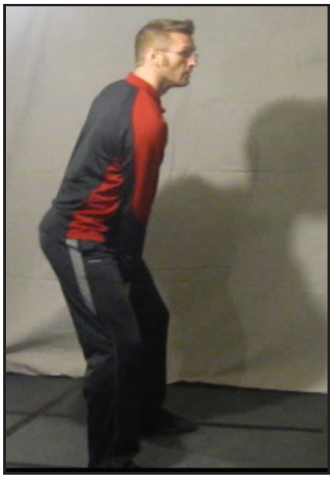

**Figure 30a.** *Kettlebell Snatch - Pre-swing*

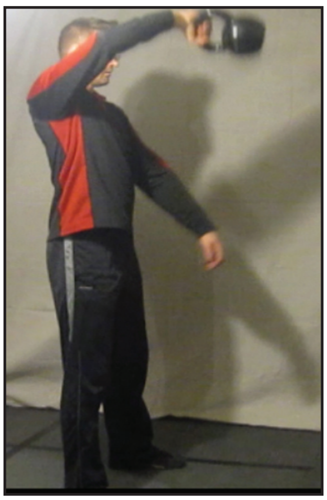

**Figure 30b.** *Kettlebell Snatch - Pull*

**Figure 30c.** *Kettlebell Snatch - Press*

### Midthigh Power Clean

The power clean is a classic strength and conditioning tool utilized in many sports. Details regarding the exercise are beyond the scope of this article, but we make a recommendation regarding the use of the midthigh positioned start  for the power clean based on the decreased hip/lumbar flexion demands for this power exercise and recent evidence which demonstrated higher power output, greater rate of force development, and greater ground reaction forces than traditional power cleans.[143,144] Many athletes will return to this exercise in their sport and discussion with their coach or strength and conditioning coach regarding supplementing this exercise in their program may be beneficial for the long term health of an HLD patient.

**Figure 31a.** *Hang Clean - Mid Thigh - Bottom*

**Figure 31b.** *Hang Clean - Mid Thigh - Pull*

**Figure 31c.** *Hang Clean - Mid Thigh - Catch*